VALIDATION OF EQUATORIAL IONIZATION ANOMALY (EIA) WITH THE IRI-2012 AND NEQUICK-2 MODELS DURING SUDDEN STRATOSPHERIC WARMING (SSW) OF JANUARY, 2009

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INTRODUCTION

- **Studies have shown that there is a coupling between the lower atmosphere, the mid atmosphere and the upper atmosphere.**

  [Pogoreltsev, 2007; Goncharenko & Zhang, 2008; Jia Yue, 2010].

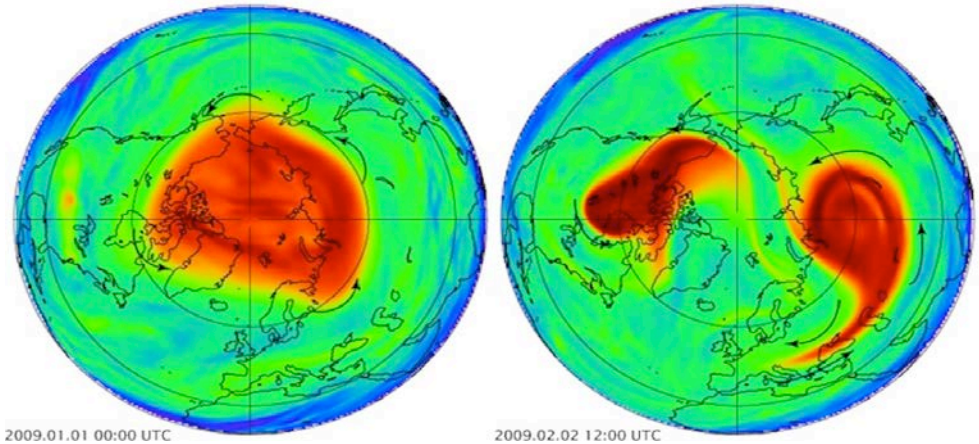
- **Atmospheric waves may propagate horizontally and vertically from their sources in the troposphere to the upper atmosphere (above stratosphere) carrying momentum and energy.**

SUDDEN STRATOSPHERIC WARMING (SSW)

- When propagating tropospheric waves get into the stratosphere, it has a meteorological effect on the winter polar stratosphere. This effect is known as the sudden stratospheric warming (SSW).

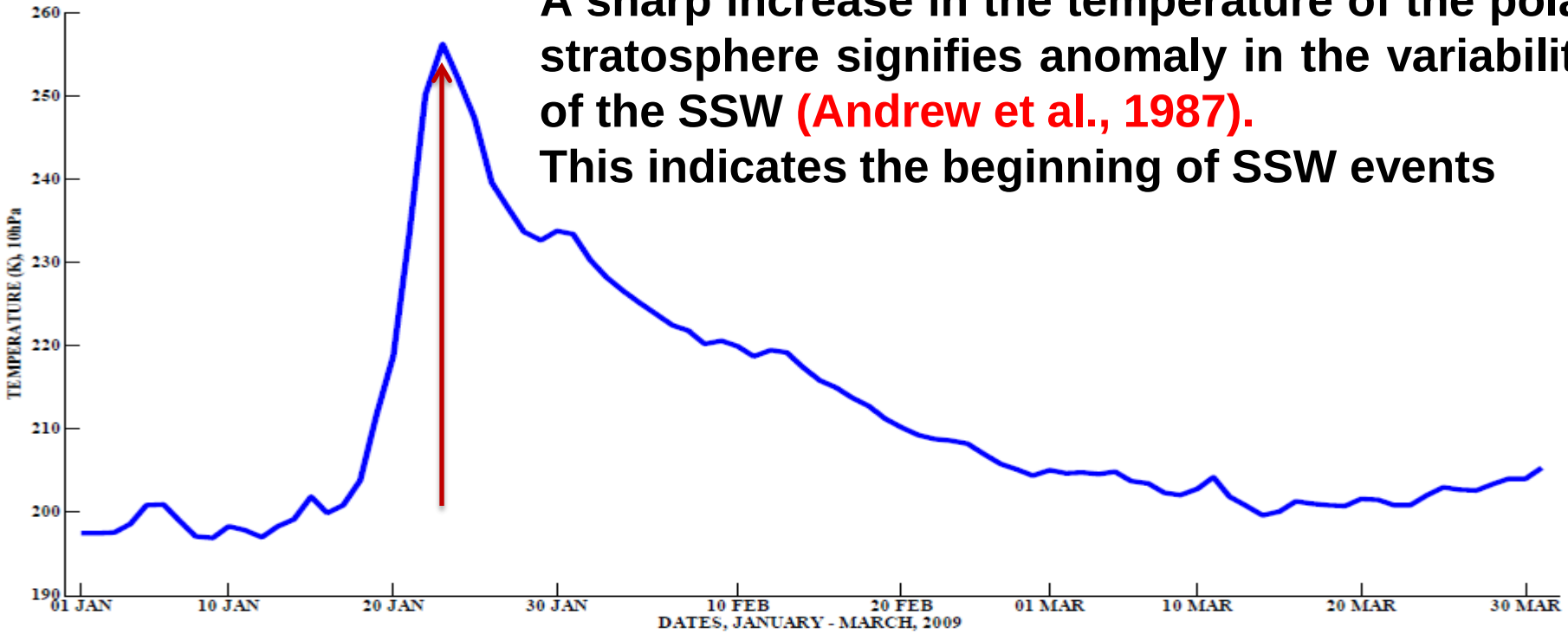
- SSW is a natural phenomenon characterized by a sudden temperature increase by several tens of Kelvin.

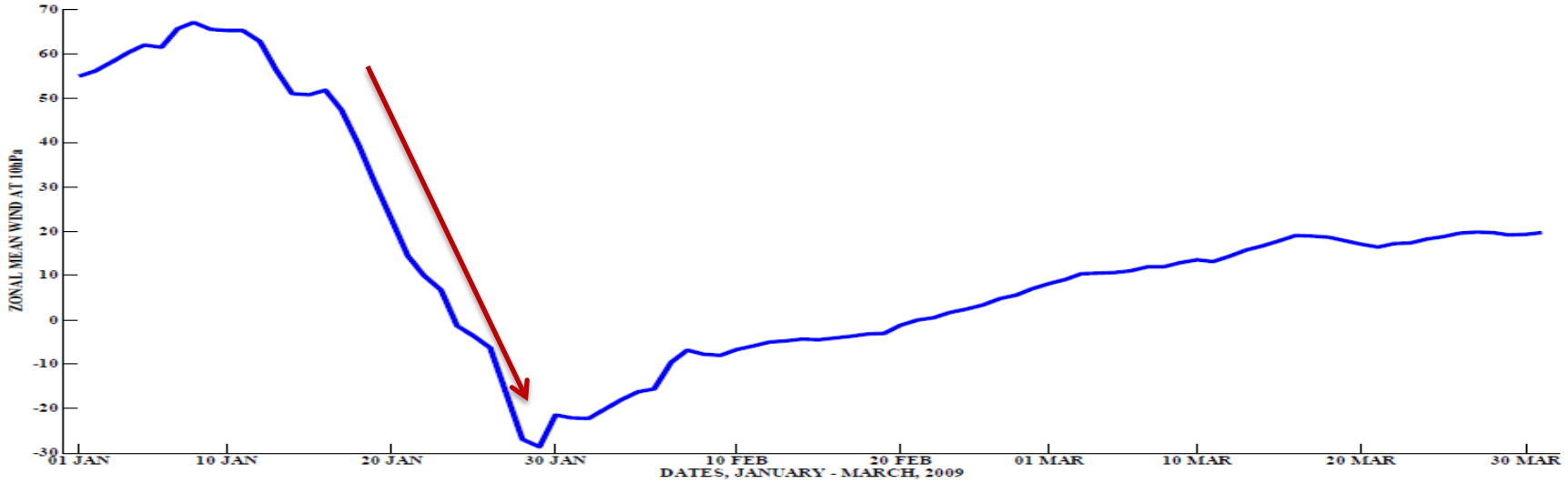
- It is also accompanied by a breakdown of the polar vortex and a slowdown (minor warming) or reversal (major warming) in the westerly wind in the winter hemisphere within few days . (Chau et al., 2011).



Dynamics of the polar vortex due to SSW.

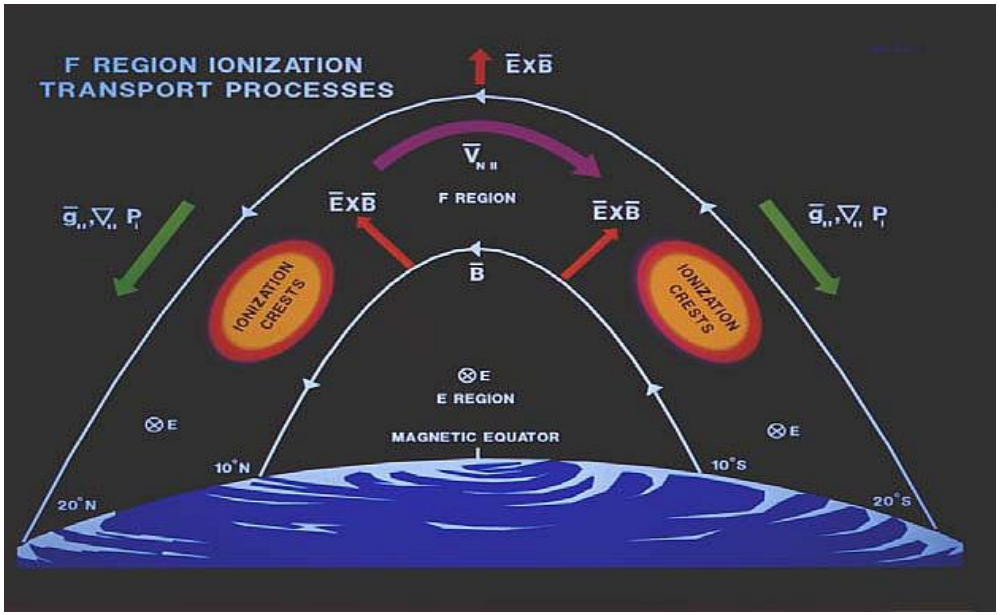
A sharp increase in the temperature of the polar stratosphere signifies anomaly in the variability of the SSW (Andrew et al., 1987).
This indicates the beginning of SSW events





EQUATORIAL IONIZATION ANOMALY (EIA)

- The EIA is the occurrence of a depression (trough) in the ionospheric parameter; TEC in the F2 layer of the geomagnetic equator and two peaks (crests) on either side of the equator at about geomagnetic latitudes (Appleton, 1946; Duncan, 1960; Wright, 1963; Hanson and Moffett, 1966; Anderson, 1973; Bhuyan and Borah, 2006; Bolaji et al., 2013).



IONOSPHERIC MODELS

- Models are used to derive data for ionospheric measurements. Such models include; IRI, SLIM, PRISM, NEQUICK etc.
  - The IRI2012
    - IRI2001
    - IRI01Cor
    - IRINeQuick
  - NeQuick 2

MOTIVATION

- The strong forcing due to SSW on the total electron content (TEC) have been investigated in other sectors of the world; America and Asia (Liu and Roble, 2002; Chau et al., 2009), while the African sector has been poorly investigated.

- The validation of two ionospheric models; the IRI and NeQuick and their TEC variability during the SSW have not been adequately investigated during SSW event over Africa. For example, investigation on TEC by Goncharenko et al. (2010) over East Africa during SSW event and its comparison with an IRI-model may not be enough to characterize African ionosphere during SSW.

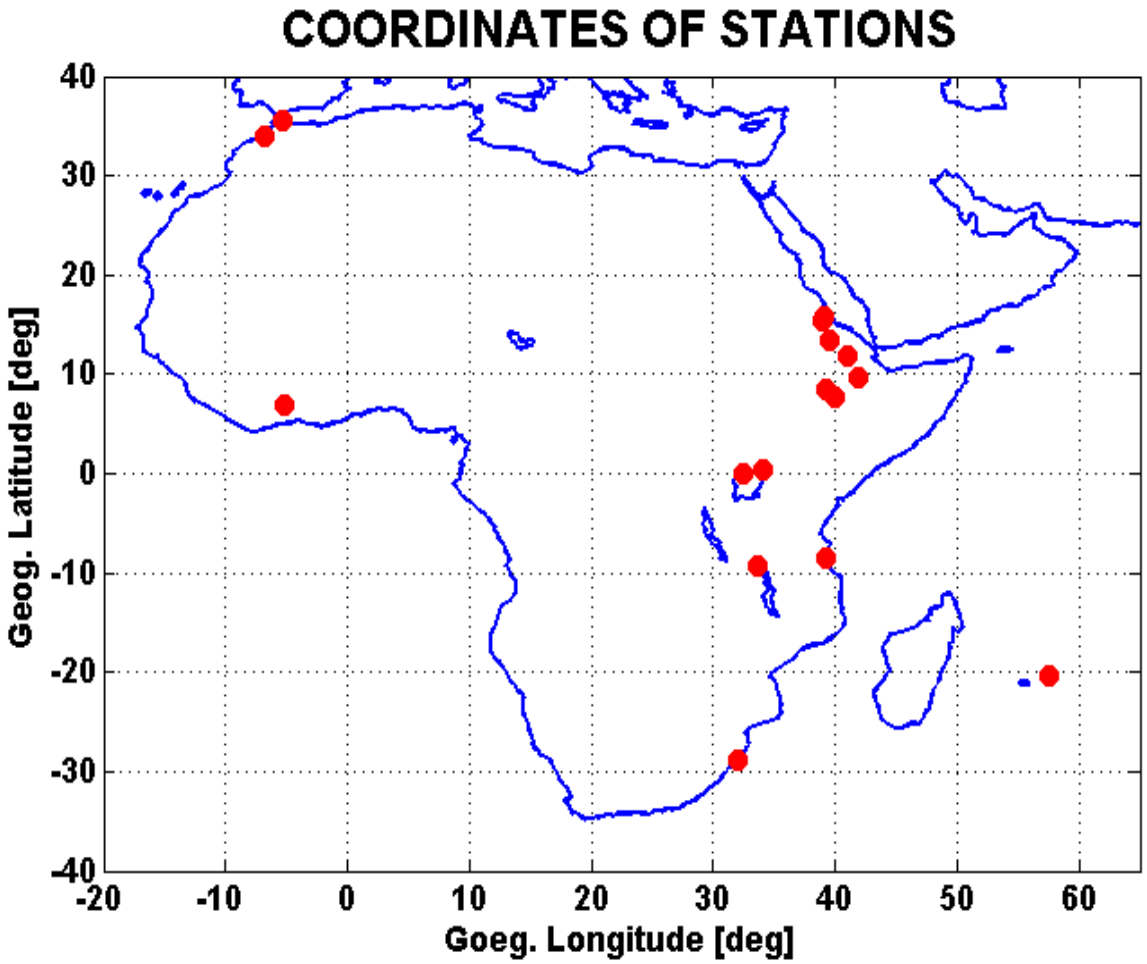
DATA

- Data from seventeen (17) GPS stations across the African region were utilized.
- The GPS data were obtained from UNAVCO http://www.ukssdc.ac.uk/cgi-bin/wdcc1/coordcnv.pl
- The IRI2012 data were obtained from: http://omniweb.gsfc.nasa.gov/vitmo/iri2012_vitmo.html.
- Three options of the IRI2012 were considered; IRI2001, IRI2001Cor and IRINeQuick.
- The NeQuick-2 data was from the ICTP at the NeQuick 2 Web Model: t-ict4d.ictp.it/nequick2/nequick-2-web-model.

STATIONS UNDER INVESTIGATION

Station	Country	Code	Geographic Coordinates		Geomagnetic Coordinates	
			Latitude	Longitude	Latitude	Longitude
TETOUAN	MORROCCO	TETN	35.56°N	5.37°W	26.15°N	79.52°E
RABAT	MORROCCO	RABT	33.98°N	6.85°W	23.92°N	80.57°E
SHEB	ERITREA	SHEB	15.85°N	39.05°E	7.07°N	110.61°E
ASMARA	ERITREA	ASMA	15.34°N	38.91°E	6.79°N	110.47°E
DAKE	ETHIOPIA	DAKE	13.48°N	39.48°E	4.91°N	111.09°E
DASM	ETHIOPIA	DASM	11.79°N	41.008°E	3.34°N	112.69°E
DAMY	ETHIOPIA	DAMY	9.6°N	41.867°E	1.13°N	113.61°E
NAZRET	ETHIOPIA	NAZR	8.57°N	39.29°E	2.90°S	77.26°E
ROBE	ETHIOPIA	ROBE	7.8°N	40.0°E	0.97°S	111.74°E
YAMOUSSOUKRO	COTE D'IVOIRE	YKRO	6.87°N	5.24°W	3.07°S	75.44°E
ENTEBBE	UGANDA	EBBE	0.05°N	32.45°E	9.52°S	104.12°E
MT. BAKER	UGANDA	BAKC	0.35°N	34.04°E	9.57°S	105.73°E
TANZANIA	TANZANIA	TANZ	8.57°N	39.29°E	16.26°S	106.30°E
TUKUYU	TANZANIA	TUKC	9.25°S	33.65°E	19.51°S	104.82°E
VACOAS METEO	MADAGASCAR	VACS	20.29°S	57.49°E	30.32°S	125.53°E
RICHARDSBAY	SOUTH AFRICA	RBAY	28.79°S	32.08°E	38.66°S	97.95°E
SUTHERLAND	SOUTH AFRICA	SUTH	32.03°S	151.05°E	41.81°S	227.85°E

STATIONS UNDER INVESTIGATION



METHOD OF INVESTIGATION

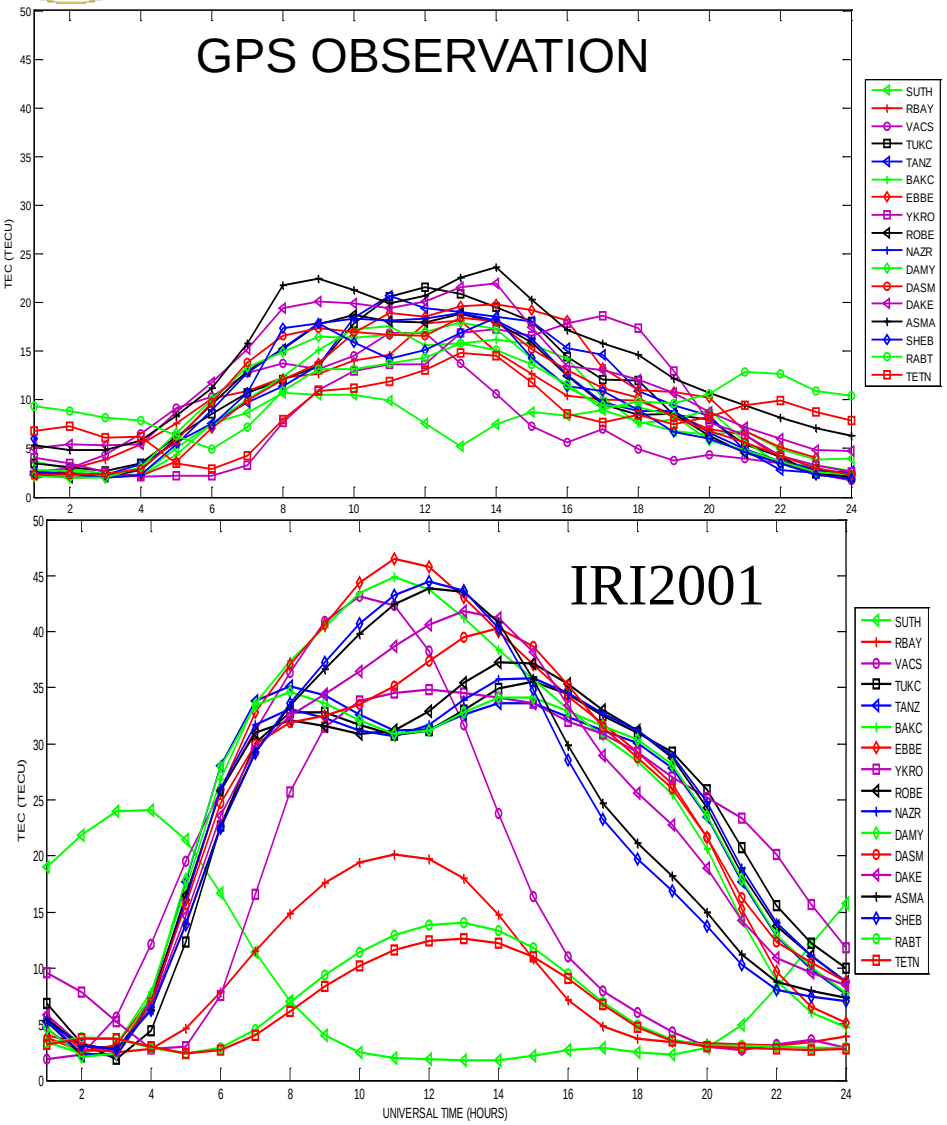
Four days were selected in January 2009 that covered period before SSW began and when it subsided:

- Pre-phase of SSW event (PPS) - 3rd Jan
- Ascending phase of the SSW (APS) – 16th Jan
- Peak phase of the SSW (PKPS) – 23rd Jan
- Descending phase of SSW (DPS) – 26th Jan

✓These selected days were repeated for each of the stations.

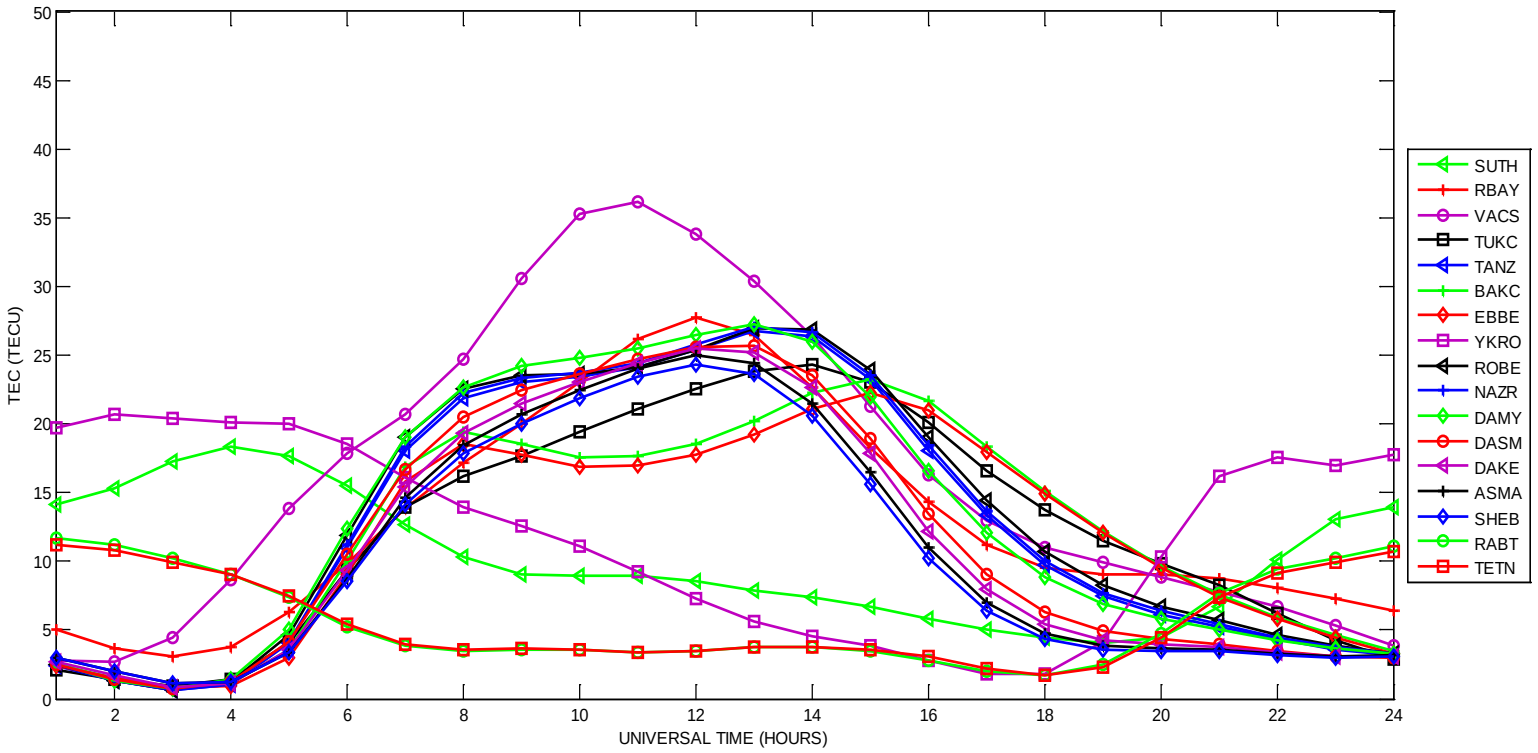
✓ Our choice of the days selected for all the phases of the SSW under investigation was based on consistent availability of data across the latitudes.

RESULTS



Variability of observed predicted TEC during PKPS across all stations.

Variability of NEQUICK-2 TEC during the PKPS across all stations

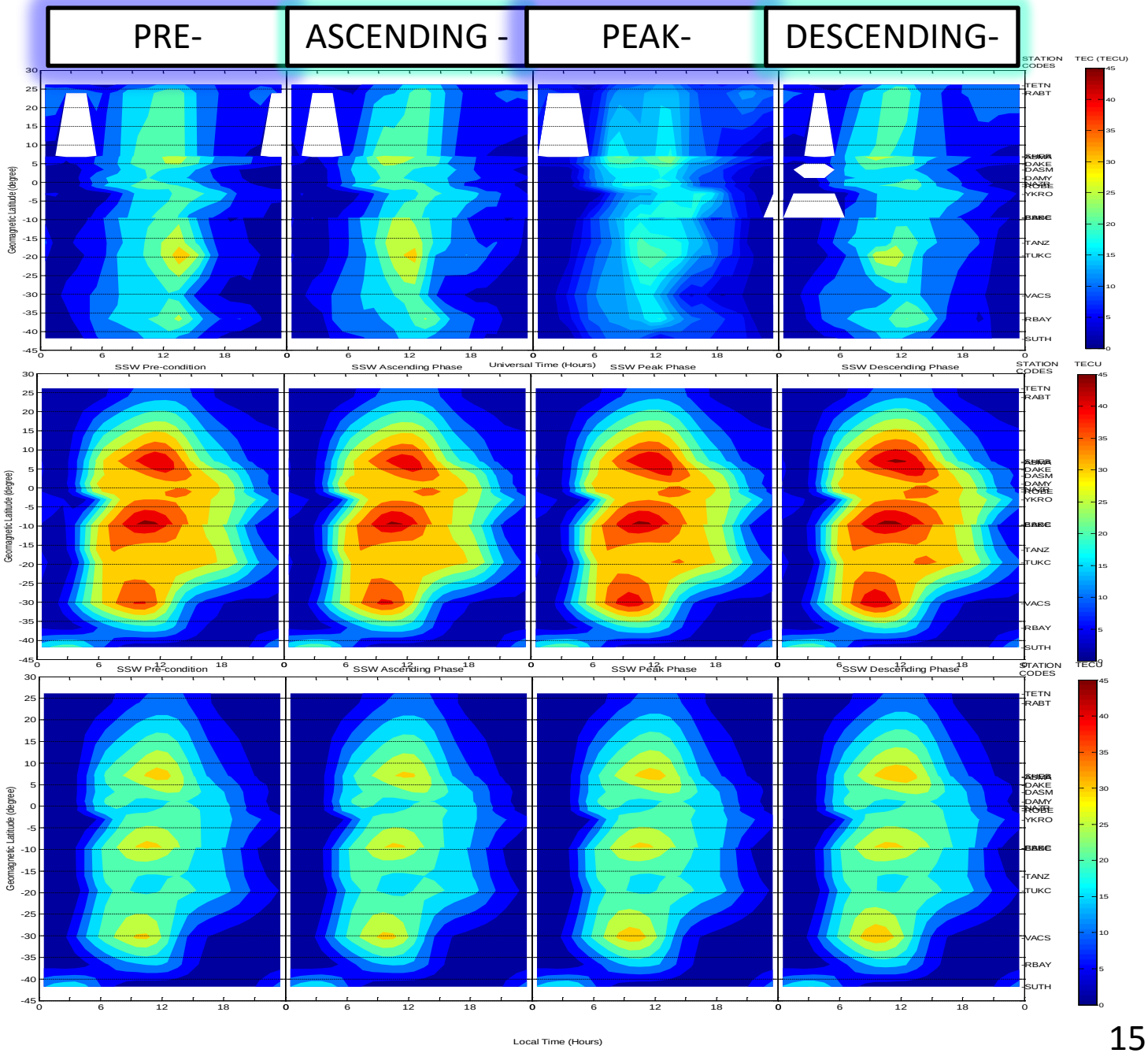


Variation of TEC from all stations during January 2009 SSW event.

GPS - TEC

IRI2001 - TEC

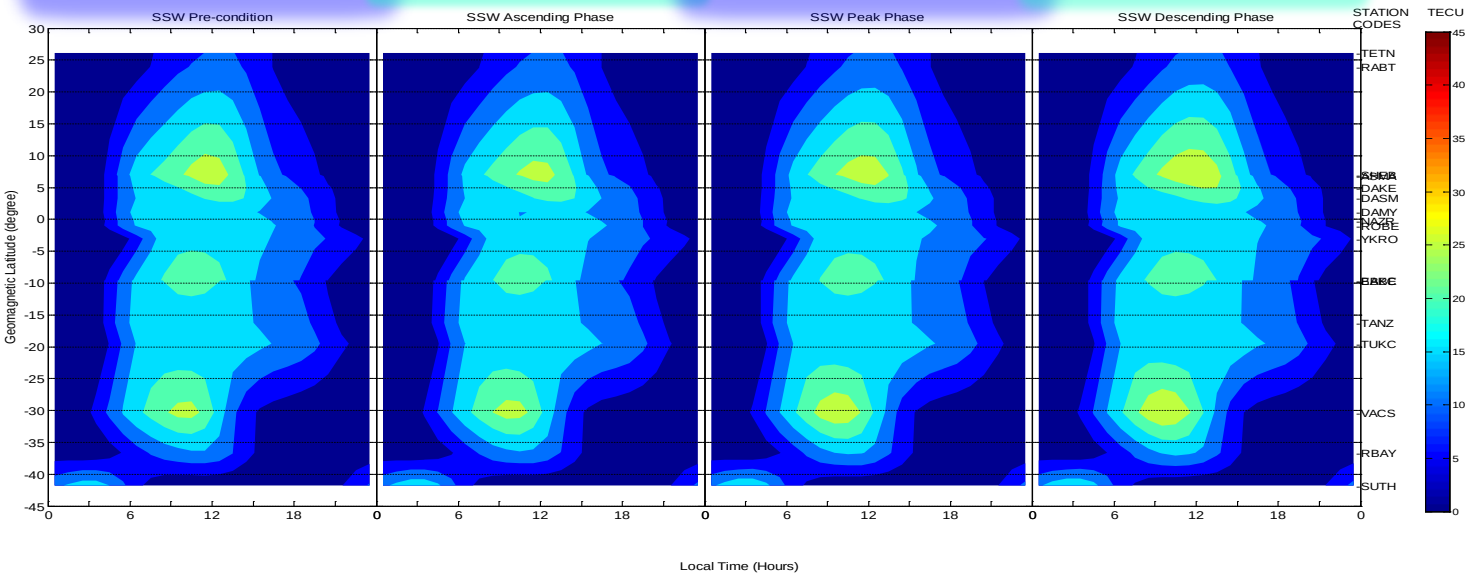
IRI2001Cor - TEC



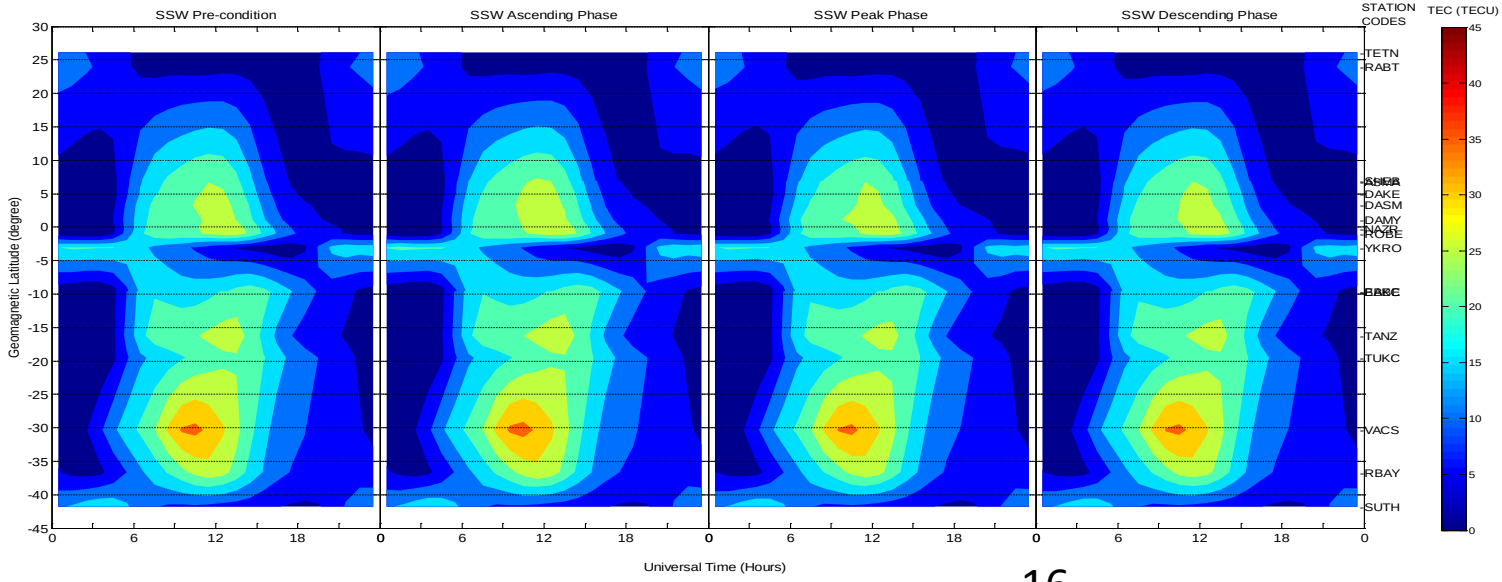
Variation of TEC for all stations during the January 2009 SSW event.

PRE-	ASCENDING -	PEAK-	DESCENDING-

IRI NEQUICK



NEQUICK_2



RESULTS

- In the northern and southern hemispheres, the models were not able to capture exactly when the EIA crest began. The developments of the EIA crests were faster for the models than the GPS observation. Also, the trough of the NeQuick-2 model were observed between ~ 3°S and ~ 7°S at all the phases of the SSW. This shows that the NeQuick-2 model failed to model the EIA trough well compared to the IRI-2012 model that reproduced the trough of the GPS observations well at equatorial latitudes.

- The suppressed and insignificant EIA development during the peak phase of the SSW event for only the observation confirms that the two models were not able to predict the sudden stratospheric warming (SSW) event.

- The EIA features of the IRI-2012 and NeQuick-2 models overestimated the observed TEC at the northern hemisphere, the southern hemisphere, the trough and even the crests in the middle latitude at all the phases during the 2009 SSW event.

- The middle latitude crests from the GPS observations resulting from the intrusion of the southern EIA crests into the middle latitude are reproduced by all the options of IRI2012 model and the NeQuick-2 model. However, the IRI2001NeQuick and NeQuick-2 middle latitude crests are stronger than their southern EIA crests.

COMPARISON OF THE EXPERIMENTAL OBSERVATIONS WITH THE MODELED RESULTS

- The IRI2012 and NEQUICK-2 models gave an earlier daytime rise in TEC between 0900UT and 1500UT than the GPS observation; which is between 1200UT and 1500UT.

- The models overestimated the values of TEC in the northern and southern hemisphere at all the phases of SSW.

- The peak phase of the SSW from the GPS observation has the weakest crest compared to the phases of the SSW from the models.

- At the PKPS, the GPS observation recorded a significant daytime depression in TEC which led to prenoon peaks at ASMA, DAKE and DASM around 1000UT but the models do not give reduced values at the PKPS.

- The models show significant intrusions of TEC from the lower latitude into the mid-latitude of the southern hemisphere; forming minor peaks at all the phases of SSW but the GPS observation show insignificant intrusions except at the PPS.

CONCLUSIONS & RECOMMENDATION

- This study shows that the IRI-2012 and NEQUICK-2 models were not able to capture the effect of SSW in the EIA region of the ionosphere.
- It also shows that forcing from the lower atmosphere (SSW) affects the variation of TEC in the ionosphere.
- IRI-2012 and NEQUICK-2 models may look into the effect of lower forcing (coupling); for example the SSW from the lower and mid atmosphere on the upper atmosphere.

ACKNOWLEDGEMENTS

- ICTP for the opportunity to present this work and also for the NeQuick 2 model.
- UNAVCO for the GPS TEC data used.

Thank You For Listening